VOL. XXVI JULY, 1916 NO. 3

THE MONIST

THE HISTORY OF SCIENCE.

INTRODUCTION.

[Dr. George Sarton is a Belgian scholar who has done much to promote the idea of a "History of Science" (as opposed to the history of any particular science, or to the sum of such particular histories.) He advocates a synthetic study that necessitates the collaboration of the scientist, the philosopher and the historian.

In 1913, Dr. George Sarton founded *Isis,* an international quarterly devoted to the history and to the organization of science, printed and published in Belgium. He himself lived a very quiet and retired life with his wife and daughter in his country home of Wondelgem, near Ghent—devoting all his time and a great deal of money to his historical studies. When the German invasion broke over Belgium, their income being entirely cut off, they had to leave their home; and after having buried all manuscripts in their garden, they went in a peasant cart to Holland, thence to England, and lastly came to this country. Dr. Sarton's library—one of the most complete on the subject he is studying—had to be abandoned: we sincerely hope that it will be saved and that Dr. Sarton will recover it after the war. He lectured in 1915 on the history of science at the summer school of the University of Illinois, at the George Washington University of Washington, and at Clark University. He has now been appointed lecturer at Harvard.

Dr. Sarton will resume the publication of *Isis* as soon as circumstances permit.—EDITOR.]

THIS essay is to explain the meaning of the history of science, to determine its limits and to show how it should be studied.

The history of science is the study of the development of science—just as one studies the development of a plant or an animal—from its very birth. We try to see it grow and unfold itself under many diverse conditions. And it is not enough—as we shall see further on—to study sep-

arately the development of each science; one has to study the development of all the sciences together. Besides, it is impossible to separate them satisfactorily one from the other; they grow together and mingle continually in innumerable ways.

There has been much research concerning the history of some particular sciences, and there are, for instance, excellent textbooks on the history of mathematics and of medicine, but there does not exist at the present day even a tolerably good history of science. The reader very likely knows the *History of the Inductive Sciences* by William Whewell, published in 1837. It was certainly a valuable book seventy years ago, but is now antiquated, and any one who does not know the history of science will do better not to use it at all. The best book that we have now at our disposal is that of Friedrich Dannemann,[1] but it is very elementary and can only be considered as a first and rough approximation. A bulky work published by Henry Smith Williams seems to be very popular in this country; at least, I have found copies of it in all the libraries where I have been. They are generally placed in the reference room where they are likely to be very often consulted. Owing to this, I feel obliged to say that these books are nothing but newspaper work, and quite unreliable.

While numberless books, many of them excellent, are published every year on the history of literature, of art, of religions, how is it that there is not yet a single history of science that can be compared with the best of them? When so many institutions, libraries, lectureships have been dedicated to the history of everything, how is it that the history of science has been so much neglected? The history of everything has been studied, except of that which

[1] Friedrich Dannemann, *Die Naturwissenschaften in ihrer Entwicklung und in ihrem Zusammenhange*. 4 vols., 1910-1913. I have analyzed this work at some length in *Isis*, II, pp. 218-222.

is the most distinctive feature of our civilization. How is that?

The most obvious, if not the best reasons, are the following. The people who have no knowledge of science, or but slight, are afraid of it. They are not inclined to read a book dealing with the history of science, because they think that they are not equal to appreciating it. Now this is a mistake: every intelligent man or woman can understand the development of science, at least if it be properly presented and taken from the beginning. More than that, I am convinced that the historical method is the best to convey scientific facts and ideas to unprepared minds and to make them thoroughly understandable,—at least that is so in the case of grown-up people. On the other hand, those who know science—or who are supposed to know it because they have made a special study in some narrow field—are often given to viewing history with contempt. They think that it is hopelessly inaccurate and, according to their own definition of science, unscientific. This is another mistake, which, however, it would take too long to completely refute. Suffice it to say that historical studies, like all other studies, are approximate; the approximation obtained by historians may be looser, but the studies are none the less scientific for that. It is not so much its degree of approximation, as a definite knowledge of this degree that gives to a study its scientific character.

At any rate, these reasons are only the most superficial ones. To set forth the others, I am obliged to make a short philosophical digression.

SCIENCE AND PHILOSOPHY.

Indeed, to make the real significance of our studies clear, it is necessary to impress the reader with a sense of the intellectual needs they must satisfy.

New scientific facts are discovered every day all over

the world and they continually make it necessary to revise our theories or to invent new ones. At the same time, science as a whole becomes more complete and deeper. Since the last century, its complexity has been developed to such a degree that now one of the first conditions of really original work is that it should be sufficiently specialized. The necessity of separating the difficulties in order the better to solve them, has made it more and more necessary to divide scientific work, and this division of labor seems to have reached a climax. That this tendency, which we may call the analytical tendency, has been extremely useful, the whole fabric of modern science is there to testify. However, its exclusive predominance is not without danger. This was not palpable in the beginning, but we see it clearly now. Indeed, the object of science is not to discover insulated facts, but to coordinate and to explain them one by the other. By dint of specialization, science would run the risk of missing its very aim; the quantity of scientific knowledge would increase, but it would be all in vain, the scientific spirit would be impoverished.

Besides, excessive analytical tendencies, without any counterpoise, would bring about another and a still graver danger: not only science would be menaced by disintegration, but our social life itself. Instead of bringing their fellow men together by giving them some common points of view, the scientists would finally be unable to understand one another.

This essential rhythm of our mind that makes us feel by turns the need of analysis and the need of synthesis, we find also in the changing idea that men have of the relations between science and philosophy. Indeed, there corresponds to it a similar rhythm which by turns brings together or drives asunder the scientist and the philosopher. A comparative study of the history of science and

of the history of philosophy would give us many opportunities to verify this.

The scientists of genius — I so call scientists whose discoveries revolutionize all accepted ideas and who originate studies of a radically new kind—have always exerted a considerable influence upon the evolution of philosophy. On the other hand, their own minds must have been of a very synthetical nature, and they have certainly borrowed much in a more or less conscious way from the philosophical store to formulate their revolutionary ideas. Think of Galilei, of Kepler, of Newton, of Darwin. Their work and influence cannot be understood, unless one takes into account these continuous interchanges between science and philosophy. They have drawn the desire of creating a new synthesis from the ideology of their time; and on the other hand, it is because their discoveries have deeply transformed this ideology that their influence has extended far beyond the scientific field where it originated.

In the same way the great philosophers—those who have really renewed the thought of their age—have also considerably influenced the progress of science. They were not themselves creative scientists, but at least they possessed all the scientific knowledge available to them. Think of Plato, Aristotle, Descartes, Leibniz, Kant. Here again, it is indispensable to conceive a double stream of ideas between science and philosophy. It is in the scientific domain that they have found at the same time the intuition of and the materials necessary to a new system; and this system in its turn, has renovated the philosophical atmosphere in which science was to pursue its development.

Therefore, those who study the history of philosophy ought to know the history of science. This is for the philosopher a heavy task, but I do not see how he can possibly escape from it. If one confines oneself to the study of, let us say, Descartes's philosophy, regardless of its conse-

quences in the field of mathematics, mechanics, astronomy, physics, medicine, botany, it stands to reason that it is impossible to give a complete or even a fair idea of his genius. Moreover, it is necessary to study the influence exerted by the Cartesian philosophy over the whole scientific thought of the seventeenth and eighteenth centuries, and even over our own science, and it is only in this way that Descartes's personality appears in its true light.

Everybody remembers those great epochs of synthesis of which Greek antiquity has given us some glorious examples, and nearer to us, the Renaissance and Cartesianism. On the contrary, during the nineteenth century, the analytical tendencies have been predominant. Synthetic construction sank into disrepute, partly as a result of the immense success of the inductive sciences, partly because most people were sick of the loose literature of the metaphysicians who came after Kant.

Whatever the case may be, a philosophical reaction was unavoidable, and this reaction still holds good, our own studies being only one aspect of it among many others. This reaction dates from the beginning of our century; it was in a great measure caused by the resounding discoveries of the last twenty-five years. First of all, the progress of physics has involved a conflict—that seemed first to be inextricable—between the classical mechanics of Galilei, Huygens and Newton, and the electromagnetical theories of Maxwell, Hertz and Lorentz, and so has brought into question the fundamental principles of natural philosophy. At the same time, the discovery of new elements having paradoxical properties, the study of new radiations, of the Brownian movement, rekindled all the controversies relating to the atomic and energetic theories and obliged the scientists to make a new survey of the principles of chemistry and to revise all their ideas about the constitution of matter. Lastly, the experiments of the biologists and the

exhumation of Mendel's ideas brought about a crisis of the transformist theories and made it necessary to reexamine all our ideas concerning the evolution of life.

However, if the philosophic revival which is now going on has been principally caused by the progress of science and only began in this century, the movement that slowly prepared it is obviously older and more complex. One must first take into account all the scientific work of the last century. This was perhaps less revolutionary and did not provoke sharp crises, like the discoveries just alluded to, but none the less it obliged scientists to modify and to elevate their point of view. Besides, it must be remembered that the writings of some of the scientists of the nineteenth century, namely Helmholtz, Claude Bernard, Berthelot, were already of a synthetical type. But a philosophic school has also in a great measure contributed to this renaissance: I refer to the positivist school represented in France by Auguste Comte, and in England by Herbert Spencer. Our own endeavors are certainly a direct result of their activity. One might say that the positivist ideas have never been better understood nor more popular than they are now. But we must not be led astray by this. It is only since the progress of science has extenuated at the same time the dogmatism and the agnosticism of the first positivist school, and made its ideals broader and more flexible, that positivism bears all its fruit.

This is the first evolution the explanation of which was necessary to show the origin of our ideas. Resounding discoveries determined very grave crises in many departments of science, and so gave a new scope to the philosophic studies that had been despised for a long time. This new philosophy is simply the old positivism, made more supple and more realistic. This is very remarkable, indeed, because the positivist philosophy that had been built up for the very use of scientists had at first not been able to

triumph over their indifference; its success was not secured until the whole structure of knowledge had been shaken and endangered by the very progress of science.

But this is not all. There is still another crisis that seems to have just reached its climax. The triumph of positivism was a triumph rather for science than for philosophy. Many people thought that philosophy would soon be incorporated into science. It would be a philosophy of science, it would gravitate around scientific facts and ideas, or it would not be at all. Its function would be to think out science, nothing more. Such exaggerations, such a misunderstanding of philosophy's historical role,—namely, to be an independent vanguard, a storehouse of general and leading ideas extracted not only from science but from the whole of human experience,—could not help bringing about a new reaction. This reaction is the intuitionism of Bergson, the radical empiricism of William James, the humanism of F. C. S. Schiller, the instrumentalism of John Dewey. I shall simply call it the pragmatist movement. By loudly asserting the claims of intuition, it asserted at the same time the rights to existence of a philosophy independent of the positive sciences. That is the only point of concern to us. And it is so much the more necessary to lay stress upon it, that, in my opinion, it is the best way to show that the conflict between neo-positivists and pragmatists, if it is partly irreducible, is, notwithstanding that, much less grave than it might appear at first sight. For one thing, we must bear in mind that we have all—philosophers, historians, scientists—the same purpose: we try to explain, to generalize, to deepen, to simplify the data of experience. And our very methods have very close analogies: all our knowledge is to a certain extent scientific knowledge, and the pragmatist himself assumes a scientific attitude when he scrutinizes his intuitions. Moreover, would the deep cause of the conflict between the positivist

and the pragmatist points of view not lie in the very complexity of our intellectual needs? These needs are of a practical, utilitarian nature and at the same time of a theoretical, esthetic nature; we need to think and to understand, but, at the same time, we need to act. Would it not lie also in the complexity of the problems raised by ever changing life? Indeed, does not life sometimes oblige the most determined agnostics to reason like pragmatists, and reciprocally? It is owing to these deep causes, inherent in our own nature and in the nature of things, that these antagonistic points of view evidence themselves and clash during the whole development of human thought. It may be well, indeed, to remember that if the pragmatist theories have appeared in a new and fascinating shape, thanks to the genius of Bergson and James, they are as old as science itself.

It is necessary to make these remarks to show that we have not to trouble ourselves too much about this crisis. Besides, positivists and pragmatists all agree in respecting science and all acknowledge the necessity of knowing it as well as possible and of having continual recourse to it. It is of the utmost concern to all of them to study the principles and the history of science. Therefore, we do not care much for their quarrels; we simply accept and record them as interesting human facts, as a new evidence of our mind's complexity.

In short, scientists and philosophers are at the present time unanimous in wishing that the general tendencies and fundamental principles of science be constantly extricated, criticized and stated with more precision. They are well aware that it is now an essential condition of progress and security. But how will it be possible to conciliate the imperious needs of synthesis and the division of labor?

It would seem that the only possible solution is that which was recommended by Auguste Comte and partly

realized by himself and his disciples: namely, to originate a new great specialty, the study of scientific generalities. To secure the unity of knowledge it will be more and more necessary that some men make a deep study of the principles and of the historical and logical development of all the sciences. Of course, they will not be expected to be perfectly acquainted with all the technical details, but they must have at their command a thorough knowledge of the great lines and of the cardinal facts of each science. It is a very difficult but not an impossible task. The inconveniences of excessive specialization will be happily counterpoised by this new branch of knowledge, which induces a collaboration of philosopher, historian and scientist. It will clearly appear from the following pages that the best instrument of synthesis, and the most natural hyphen between scientist and philosopher is the history of science.

THE HISTORY OF SCIENCE.

Auguste Comte must be considered as the founder of the history of science, or at least as the first who had a clear and precise, if not a complete, apprehension of it. In his *Cours de philosophie positive,* published from 1830 to 1842, he has very clearly brought forward the three fundamental ideas which follow: (1) A synthetic work like his cannot be accomplished without having constant recourse to the history of science; (2) It is necessary to study the evolution of the different sciences to understand the development of the human mind and the history of mankind; (3) It is insufficient to study the history of one or of many particular sciences; one has to study the history of all sciences, taken together. Besides this, as early as 1832, Auguste Comte made an application to the minister Guizot for the creation of a chair, devoted to the general history of sciences (*histoire générale des sciences*). It was sixty years before this wish of his was granted, and the course

entrusted to Pierre Laffitte was inaugurated at the Collège de France in 1892, thirty-five years after Comte's death. Another French philosopher, Antoine Cournot, also contributed to the clearing up of our ideas, namely by the publication in 1861 of his book *Traité de l'enchaînement des idées fondamentales dans les sciences et dans l'histoire.* However the real heir to Comte's thought, from our special point of view, is neither Laffitte nor Cournot, but Paul Tannery. It is hardly necessary to say much of him, because all who have the slightest knowledge of the history of science must needs have come across one of his numerous memoirs, all so remarkable for their originality and exactitude. Paul Tannery himself attached importance to his intellectual connection with Comte and often expressed his admiration for the founder of positivism.

Tannery's philosophy is very different from Comte's, but the greatest difference between them is that Comte's knowledge of the history of science was very superficial, whereas Paul Tannery, being extremely learned and having at his disposal a mass of historical research work which did not exist in the thirties, knew more of the history of science than anybody else in the world. Certainly no man ever was better prepared to write a complete history of science, at least of European science, than Paul Tannery. It was his dream to carry out this great work, but unfortunately he died in 1904.

One can understand the history of science in different ways, but these different conceptions do not contradict each other; they are simply more or less comprehensive. My own conception does not differ much from Tannery's, except that I attach more importance to the psycho-sociological point of view.

Auguste Comte had noticed all the bonds that unite the different sciences, but he did not give enough attention to them. If he had understood that these interactions and this

interdependence have existed in all directions from the very beginnings of science, would not the rigid framework of his *Cours de philosophie* have been burst asunder?

On the other hand, some people seem to think that it is impossible to write the history of science as a whole, that the subject is too great. I should rather say that the very impossiblity is to pick out from this inextricable network the development of one single branch of human knowledge. Moreover it is actually impossible to write the history of any important discovery without writing, willingly or not, a chapter of the history of science—I mean the history of science as a whole. How could we explain, for instance, the discovery of the circulation of the blood if we did not explain the evolution of anatomy, of comparative zoology, of general biology, of natural philosophy, of chemistry, of mechanics? Likewise, to make clear how they succeeded by degrees in determining longitudes at sea, one has to resort to the history of pure and applied mathematics, the history of astronomy and navigation, the history of watch-making, etc. It would be easy enough to give more examples of the same kind.

Further, it is only by considering the history of science as a whole that one can appraise the scientific level of a definite period or of a definite country. It has happened more than once indeed that one science became neglected while others were thriving, or that scientific culture moved from one country to another. But the historian is not deluded by these facts, and he does not think that human genius is suddenly quenched or rekindled; from his synthetical standpoint he sees the torch of light pass from one science to the other or from one people to another. He perceives better than anybody else the continuity of science in space and time, and he is better able to estimate the progress of mankind.

But the historian's mind is not satisfied with the study

of the interactions between the different sciences. He wishes to study also the interactions between the different sciences on one hand and all the other intellectual or economic phenomena on the other hand. As a matter of fact he has to give a great deal of attention to these reciprocal influences, but of course he does not forget that the aim of his work is essentially to establish the interconnection of scientific ideas.

In short, the purpose of the history of science, as I understand it, is to establish the genesis and the development of scientific facts and ideas, taking into account all intellectual exchanges and all influences brought into play by the very progress of civilization. It is indeed a history of human civilization, considered from its highest point of view. The center of interest is the evolution of science, but general history remains always in the background.

It follows from this definition that the only rational way to subdivide this history is not at all to cut it up according to countries or to sciences, but only according to time. For each period of time, we have to consider at once the whole of its scientific and intellectual development.

Of course to make this general synthesis possible, it will often be expedient, or even necessary, to write monographs or partial syntheses of different kinds. For instance, the study of the archives of a definite place leads naturally to the drawing up of an essay on the history of science in that place. On the other hand, a specialized scientist will be tempted to look up the genealogy of an idea in which he is particularly interested, or to write the biography of a forerunner whose work and genius he can better appreciate than anybody else. But all this research is necessarily incomplete and does not acquire its proper significance so long as it cannot be properly inserted into a history of the sciences of the same age. It may be worth while to add that all monographs are not equally useful; some are so

clumsy and absurd that they obscure, mislead and delay the next synthesis.

To elaborate our historical work we have, of course, to use the same methods that are used by ordinary historians to appraise and criticise the materials available to them. But the historian of science has to use, independently, some other methods of a more special nature. I cannot explain them here, but it is easy to understand that, for instance, to establish at what date a discovery became a real part of science and enriched human experience, the historial exegesis must be supplemented by a scientific exegesis, based on the evidence given by the positive sciences.

We must try to marshal all scientific facts and ideas in a definite order; this means that we must try to assign to each of them a date as precise as possible—not the date of their birth or of their publication, but that of their actual incorporation into our knowledge. Likewise biographers have to exert themselves to fix precisely during which periods the influence of great scientists was the most felt, in order to range them in chronological series. That is generally a very difficult thing to do, and the reader will not fail to appreciate the work that is discreetly accomplished by such scholars. This work of erudition is the bed-rock on which all historical writing is built up.

These remarks complete and add precision to our definition of the history of science. However it may be well to give some more details about the different exchanges which the historian has to consider to put the evolution of science in its proper light.

I shall successively examine some of the other departments of life which are the most interesting for the historian of science: (1) General history or the history of civilization; (2) The history of technology; (3) The his-

tory of religions; and (4) The history of fine arts and arts and crafts.

1. *Science and Civilization.* Since the eighteenth century, and notably under the influence of Vico, Montesquieu and Voltaire, the conception of history has become more and more synthetical. History, the principal interest of which consisted in military records and court annals, is growing up into a history of civilization. It stands to reason that a sufficient knowledge of the history of civilization is absolutely necessary, were it only to locate the scientific facts in the very surroundings that gave rise to them.

On the other hand the historian of civilization can no longer remain unacquainted with the history of science. Some of the most recent historical manuals contain paragraphs devoted to it. It is true, the space allowed is rather scanty, but that is a beginning. I feel confident that before long general histories will be written where the history of science, far from being banished to some obscure corner, will be, on the contrary, the very center of the picture. Is not science the most powerful factor of evolution?

Some examples will illustrate the signification of the history of civilization: How can one account for the fact that the Latin manuscripts containing the translations of Greek authors made from Arabic texts, have so long barred the way to the printed translations that had been elaborated direct from the Greek texts? The latter, indeed, were much better. Björnbo has given some reasons that are very probably the true ones. The printed books that nobody cared to copy, became rarer and rarer. On the other hand the manuscripts were copied over and over again and continually multiplied. Besides, the copyists lacked knowledge and critical sense to a great extent, and they could not help being favorably impressed by the bulk of

Arabic literature. Mere scientific reasons do not suffice to explain the creation of the metrical system by the French revolutionaries. This creation was also in part a reaction against the "foot of the king" of the *ancien régime*. Financial or tariff regulations or the promulgation of labor laws can transform the business life of a country and, indirectly, its scientific production. To understand the beginnings and development of geography one has to take into account many facts that are quite foreign to science. For instance: the quest of mythical treasures; conquerors' ambitions; religious proselytism; the adventurous instincts of daring young men. Lastly, it is necessary to know the history of epidemics and to study all the social facts that have been their causes or their results, to correctly estimate the evolution of medical ideas.

2. *Science and Technology.* Industrial requirements are always putting new questions to science, and in this way they guide, so to say, its evolution. On the other hand the progress of science continually gives birth to new industries or brings new life into old ones. It follows that the history of science is constantly interwoven with the history of technology, and that it is impossible to separate one from the other.

Let us see some examples. After exhausting-pumps had been invented there was such a demand for good pumps of this kind that special workshops were founded in the beginning of the eighteenth century, in Leyden, Holland, to make them, and of course these workshops soon undertook to make other scientific instruments. It is hardly necessary to point out how much the making of these instruments is intimately connected with the history of physics or astronomy.

A geological discovery suffices to revolutionize a whole country and transform an agricultural nation into an in-

dustrial one. Of course a transformation as complete as this involves a radical change in scientific needs. The working of mines has always exerted such a deep influence on the evolution of science and civilization that one might compare the importance of mines in the history of science with that of temples in the history of art. L. de Launay has very clearly shown that the silver mines in Laurion played a considerable part in the history of Greece.

The history of chemistry would sometimes be unintelligible if the history of chemical industries was not studied at the same time. Let me simply remind the reader of the case of coloring matters. Industrial research made in this direction has deeply influenced the progress of organic chemistry. On the other hand it is well known how much has been done to improve this industry by the scientists of the German Chemical Society.

A chemical discovery can revolutionize a whole country, just as completely as a geological one; as soon as it becomes possible to realize, on a business basis, the chemical synthesis of a natural product (like indigo, vanilla, India rubber), the agricultural industry and civilization of immense countries will be in danger.

Technical inventions are every day more precisely determined by industrial needs. The manufacturer can often say very definitely to the inventor: "This is the invention which I now need to improve my production." Besides, every invention starts a series of others that the first has made necessary and that it would have been impossible to realize, or even to conceive, before.

Lastly, commercial needs also influence the development of the sciences, not only the natural sciences and geography (that is too obvious to dwell upon), but even mathematics. It is necessary to take into account the evolution of bookkeeping and banking business to thoroughly understand the introduction and the spread of Hindu-

Arabic numerals into Europe, and later the invention of decimal fractions. It is also a great deal owing to commercial requirements that many astronomical discoveries were made, and that the different systems of weights and measures were created.

3. *Science and Religion.* Science and religion never ceased to influence one another, even in our own time and in the countries where science has reached a high degree of perfection and independence. But of course the younger science was, and the farther we go back through the ages, the more numerous these interactions are. Primitive people cannot part scientific or technical ideas from religious ones, or, more exactly, this classification has no sense to them. Later, when the division of labor had created some scientists or engineers, distinct from the priests, or at least had given birth to a class of priests who had undergone a higher scientific training than their colleagues, even then the interpretation of the holy books, the observance of rites, the needs of agriculture and medicine, the making of the calendar, and above all, the hopes, the fears and the anxieties of a very precarious existence, have been innumerable links between science and religion. The great plagues, and generally all cataclysms, for instance earthquakes or wars, have been followed by religious revivals and often by violent outbursts of religious fanaticism.

On the other hand I know many cases where the priests themselves have been the transmitters of knowledge from one generation to the following. The best example of this can be found during the period extending from the end of the second school of Alexandria to the ninth century. We owe, if not the advancement of science, at least its conservation, to the Fathers of the Latin church and to the Nestorian heresy.

In some other cases the influence of religion is less

direct, but not less important. For instance A. de Candolle has proved that the Protestant families which were exiled from the Catholic countries of Europe during the sixteenth and seventeenth centuries and even during the eighteenth, have given birth to an extraordinarily high number of distinguished scientists. That is not to be wondered at. These people who preferred the misery of exile to moral servitude, were certainly above the average as to their conscientiousness and earnestness.

The interactions between science and religion have often had an aggressive character. There has been most of the time a real warfare. But as a matter of fact it is not a warfare between science and religion—there can be no warfare between them—but between science and theology. It is true that the man in the street does not easily differentiate between religious feelings and faith, on one side, and dogmas, rites and religious formalism on the other. It is true also that the theologians, while affecting that religion itself was aimed at when they alone were criticized, have not ceased from aggravating these misunderstandings. An excellent proof of this has been given in this country. One of the great men of these United States, Andrew Dickson White, has published a splendid book on *The Warfare Between Science and Theology*. Mr. White is a very godly man, and his book is, it is hardly necessary to state, extremely liberal and indulgent to everybody. Notwithstanding this, the author and his book had to bear the attacks of a great many fanatics.

One of the saddest results of these misunderstandings is that some very religious and sincere souls have been misled and have treated science as an enemy. Another important result is that the evolution of science is very intimately interwoven with that of religions and their heresies.

4. *Science and Art.* It may be useful to tender some

remarks upon the different characteristics of scientific and artistic work before pointing out what is interesting from our point of view in the history of art. In the history of art as it is generally taught, very little is said about technicalities. Are there many people who know, or care to know, what kind of colors Botticelli used, or what were the tools of Phidias? We love a work of art for itself. It is essentially the ultimate result that interests us, not the methods employed to obtain it. On the contrary in the domain of learning the result is generally less interesting than the methods employed to reach it.

The history of science is not merely a history of the conquests of the human mind, but it is much more a study of the instruments—material and intellectual instruments —created by our intelligence; it is also a history of human experience. This long experience of the past has much more significance for the scientist than for the artist. The artist admires the work of his forerunners, but the scientist does more than admire, he makes actual use of it. The artist may find an inspiration in it, but the scientist tries to incorporate it entirely in his own work. It is very difficult to conceive progress in art. Does Rodin carve better than Verrochio or Polycletus? The pictures by Carrière, by Watts, or by Segantini, are they finer than those by Fra Angelico, by Van Eyck or by Moro? Have these questions even any sense?

In the domain of science the matter is quite different. Undoubtedly it would be foolish to discuss whether Archimedes was more or less intelligent than Newton, or Gauss; but we can in all security assert that Gauss knew more than Newton, and that Newton knew more than Archimedes. The making of knowledge, unlike that of beauty, is essentially a cumulative process. By the way, this is the reason why the history of science should be the leading thread in the history of civilization. Nothing that has been done or

invented gets lost. Every contribution, great or small, is appreciated and classified. This cumulative process is so obvious that even very young men may be better informed and more learned than their most illustrious forerunners. As a matter of fact they are standing on the shoulders of their predecessors, and so they have a chance to see farther. If they are not very intelligent they may be inclined to think that it is useless to study history, under the misapprehension that they already know of the past all that is really worth knowing. In short, we are not sure that men become more intelligent—that is, whether intelligence increases—but we positively know that human experience and knowledge grow every day. As I have said, one does not pay much heed to mediocre artists. What they do has not much importance. On the contrary, in the laboratories, libraries and museums where science is slowly growing,—like an ever-living tree,—enormous quantities of excellent work is done by thousands of men who are not unusually intelligent, but who have been well trained, have good methods and plenty of patience.

Scientific work is the result of an international collaboration, the organization of which is perfected every day. Thousands of scientists devote their whole lives to this collective work—like bees in a hive—but their hive is the world. This collaboration does not take place simply in space, but also in time; the oldest astronomical observations are still of some use. Perhaps this collective nature of scientific work is one of the causes of the general indifference concerning its history—indifference strongly contrasting with the widespread curiosity about the history of literature and the fine arts. Science aims at objectivity; the scientist exerts himself to decrease to a minimum his "personal equation." Works of art on the contrary are extremely individual and passionate, so it is not to be wondered at that they excite more sympathy and interest.

The history of the fine arts and of literature is generally considered as a history of the great artists and of the works they have bequeathed to us. But one could adopt a different point of view: just as the history of science gives us the materials of an evolution of human intellect, so one could look in the history of the arts and of literature for the story of the evolution of human sensibility. The history of science is a history of ideas; just so the history of art could be considered as a history of man's dreams. Understood in that way, the two histories complete and enlighten one another.

The interactions between science and art have been particularly vivid at the times of naturalistic reactions against scholastic and pedantic excesses. It would be extremely interesting to make a closer study of the rhythm of the different tendencies that swayed plastic arts and music, and to look for similar rhythms in the contemporary succession of scientific theories, or more exactly, attitudes. The interference of some men of genius, who were at one and the same time artists and scientists,—such as Leonardo da Vinci, Albrecht Dürer and Bernard Palissy,—gives us a splendid opportunity to study these interactions in their deepest and most fascinating form. On the other hand it is a fact that scientific ideas have often been transmitted by works of art; moreover for all the period that precedes the beginnings of popular printing these works of art give us direct testimonies—often the only ones we have—of inestimable value. For instance it would be impossible to trace the history of ancient chemistry but for all the works of art and decoration that have come to us; and, to understand the history of chemistry, not only in ancient times but even as far as the threshold of the seventeenth century, it is still necessary to study the development of the arts and crafts,—the art of the potter, of the glassmaker, of the

chaser, of the jeweler, of the miniature painter, of the enameler.

But the history of art helps us, above all, to understand the spirit and the soul of vanished civilizations. From this point of view, works of art have an immense superiority over every other manifestation of the human mind; they give us a complete and synthetical view of times gone by; they offer us the information that we need at a glance; they bring the past to life again. A granite sphinx, a Nike, a picture by Giotto or by Breughel, a Gothic cathedral, a mass by Palestrina—all these things teach us more in one flash that living men could do by long discourses.

The following examples will show what kind of information the history of art can give us. It is by comparing Gothic monuments that Viollet le Duc has been able to find out some of the principal commercial roads of the twelfth century. Illustrations from Roman monuments give us exact information as to the origin of domestic and medical plants. Indeed it is through Greece and Rome that most of them were introduced from the East into Europe. The history of these plants tells us all the vicissitudes that modified the commercial and intellectual relations between those peoples. Here is another very curious fact. The great botanist H. de Vries has discovered the variety *monophylla* of *fragaria vesca* in a picture by Holbein the Elder ("The Saint Sebastian of Munich," dated 1516). This variety is now cultivated in botanic gardens as a rarity. One guesses that similar discoveries, however small they may appear, sometimes accomplish the solution of historical problems.

Lastly, I wish to note that the history of science is also, to a certain extent—perhaps less than some mathematicians think, but much more than the artists suppose—a history of taste. Leaving aside the external beauty of many books of science, for many scientists were splendid

writers (think of Galilei, Descartes, Pascal, Goethe, Darwin), the very substance of their work has often a great esthetical value. Scientists, who are men of taste, very easily distinguish the scientific theories that are beautiful and elegant from the others. It would be wrong to ignore this distinction, because this beauty and harmony, that common people cannot see but that the scientist does see, is extremely deep and significant. One might ask: "These theories that are more beautiful—are they more true?" Anyhow they are easier and more fertile; and for that reason alone it is worth while to give them our preference.

THE SCIENTIFIC POINT OF VIEW.

The history of science has a great heuristic value, especially if it has been worked out by somebody who is well acquainted with modern scientific tendencies as with ancient ones. The sequence of old discoveries suggests similar concatenations to the scientist, and so enables him to make new discoveries. Disused methods, cleverly modified, may be rendered efficient again. When it is understood in this way, the history of science becomes really a research method. A great scientist of our own time, Ostwald, has even gone so far as to say that "It is nothing but a research method." We do not admit this much. Anyhow, new and old science complete and continuously help one another to advance and to diminish the unknown that surrounds us everywhere. Does this idea not illuminate our conception of the universal scientific collaboration? Death itself does not interrupt the scientist's work. Theories once unfolded are eternally living and acting.

To give to our history all its heuristic value, it is not sufficient to retrace the progress of the human mind. It is also necessary to remember the regressions, the sudden halts, the mishaps of all kinds that have interrupted its

course. The history of errors is extremely useful; for one thing, because it helps us to better appreciate the evolution of truth; also because it enables us to avoid the same mistakes in the future; lastly, because the errors of science are of a relative nature. The truths of today will perhaps be considered tomorrow, if not as complete mistakes, at least as very incomplete truths; and who knows whether the errors of yesterday will not be the approximate truths of to-morrow? Similar rehabilitations frequently occur, and the results of historical research often oblige us to admire and honor people who have been misunderstood and despised in their own time. This incidentally proves to us that the study of the history of science has also some moral advantages.

However the history of superstitions and errors must not make us forget that it is the history of truth—the most complete and the highest truths—that interests us primarily. Besides, one may aim at retracing the history of truth in its entirety, because it is naturally limited, but the history of errors is infinite. It is thus necessary to fix some artificial limits to the latter and to choose judiciously between the errors and superstitions. A great simplification is obtained by classifying the errors in groups. Indeed the same mistakes and superstitions appear over and over again in different shapes, and it is useful to know the different types of errors to understand the mechanism of intellect.

It is much to be regretted that many scientists decline to admit the utility of historical research or consider this simply as a kind of pastime of small importance. They base their contempt on the following argument: "All the best of ancient science has been assimilated and incorporated in our own science. The rest did not deserve more than oblivion, and it is awkward to overburden our memory with it. The science that we are learning and teaching

is the result of a continuous selection which has eliminated all the parasitic parts in order to retain only that which is of real value."

It is easy to see that this argument is not sound. For one thing, who will guarantee that the successive selections have been well made? This is so much the more a matter of doubt that this selective and synthetic work is generally done not by men of genius, but by professors, by authors of textbooks, vulgarizers of all kinds, whose judgment is not necessarily irreproachable and whose intuitions are not always successful. Besides, as science is constantly evolving, as new points of view are introduced every day, any idea that has been neglected may be considered later on as very important and fertile. It often happens also that some facts that were scarcely known all at once become very interesting, because they can be inserted into a new theory that they help to illustrate. Of course scientific syntheses—like those represented by our textbooks—are indispensable. Without them science could hardly be transmitted from one generation of scholars to the next, but it must be understood that they are always provisional and precarious. They must be periodically revised. Now how would that be possible if the history of science did not show us our way through all the unutilized experience of the past? History is, so to say, the guide—the catalog—without which new syntheses and selections made from fresh points of view would hardly be possible. All the vicissitudes and recantations of science prove conclusively that no man can ever flatter himself that he has definitely and completely exhausted a scientific fact or theory. No particle of human experience, however small, can be entirely neglected. To assert this is to assert, at the same time, the necessity of historical research.

Moreover among scientific works there are some, the genesis of which cannot be explained in the ordinary ana-

lytical way. They introduce abrupt discontinuities into the evolution of science because they so far anticipate their own time. These works of genius are never entirely known, and the interest they offer is never entirely exhausted. It is perhaps because it is almost inexhaustible, that true genius is so mysterious. Sometimes centuries pass before the doctrines of a man of genius are appraised at their true value. A great deal of benefit is still to be reaped from the reading of the works of Aristotle, Diophantus, Huygens or Newton. They are full of hidden treasures. For it is a gross mistake to think that there is nothing more in such works than the facts and ideas which are positively formulated; if that were true it would of course be useless to refer to them, the enunciation of these facts and ideas would suffice. But that is not true, and I cannot but advise those who have any doubt about it, to try. They will find that nothing excites the mind more than this return to the sources. Here also it is the historian's business to point out to the scientist the very sources where he will the most likely invigorate his mind and get a fresh impulse.

I wish now to give a few examples to illustrate the preceding remarks. Any amount of them can be found in the history of medicine; we need but recall how greatly the whole of medical evolution has been influenced by the Hippocratic teaching, our modern ideas on humorism and naturism; or, again, the organotherapic theories. Not only are the old ideas restored to vogue, but it sometimes seems that a kind of rhythm brings them back to light periodically. Likewise Georges Bohn has shown the periodical return, in the domain of comparative psychology, on one hand, of the animistic and anthropomorphic conceptions, on the other hand, of the positivist conceptions. As a rule the further science is removed from the mathematical form the more likely these vicissitudes. One can also say that when science is more accurate, that is to say, when the domain

of uncertainty and hypothesis becomes narrower, the oscillations of the mind between divergent points of view are so much less numerous,—but they do not cease entirely. Thus E. Belot has recently reintroduced into cosmology, in a very seductive shape, the vortex theory that one would have thought had been entirely banished by Newton's criticisms. Similarly Walter Ritz has given weighty reasons for reinstating into optics the emission theory, which seemed to have been forever exploded by the discoveries of Huygens, Young and Fresnel.

But the best examples of such return to ancient knowledge are given to us by the history of technology. The history of chemical industries is very significant from this point of view. This is due to the fact that economic conditions here play a considerable part. In order that an invention may be realized it does not suffice that it be theoretically possible; it must pay. Now thousands of circumstances continually modify the material factors which the engineer is struggling with; many are of such a nature that nobody could foresee them, or (what amounts to the same thing), that it would cost too much to insure oneself against all of them. If new products appear on the market, or if the prices of some of the raw materials happen to vary considerably, or if new discoveries are made, or if new residues are to be employed, old methods that were too expensive may become economical, or reciprocally. Hence the chemist and the engineer have a vital interest in knowing the processes that have fallen into disuse, but to which the very progress of science may give from one day to the next a new career. The history of science is to them, so to say, what forsaken mines are to the prospector.

But in my opinion, however important its heuristical value may be, there are still deeper reasons why the scientist should give his attention to the history of science. I am thinking of those which have been so splendidly illus-

trated by Ernst Mach in his *Mechanics*. For one thing, it is obvious that "they that know the entire course of the development of science will, as a matter of course, judge more freely and more correctly of the significance of any present scientific movement than they who, limited in their views to the age in which their own lives have been spent, contemplate merely the momentary trend that the course of intellectual events takes at the present moment."[2] In other words, to understand and to appraise at its just value what one possesses, it is well to know what the people possessed who came before us; this is as true in the domain of science as it is in daily life. It is his historical knowledge that discloses to the scientist his precise attitude toward the problems with which he has to grapple, and that enables him to dominate them.

Moreover while research workers exert themselves to extend the boundaries of science, other scientists are more anxious to ascertain whether the scaffolding is really solid and whether their more and more daring and complex edifices do not risk giving way. Now the task of the latter, which is neither less important nor less lofty than that of discovery, necessarily implies a return to the past. *This critical work is essentially of an historical nature.*[3] While it helps to make the whole fabric of science more coherent and more rigorous, at the same time it brings to light all the accidental and conventional parts of it, and so it opens to the discoverer's mind new horizons. If that work were not done, science would soon degenerate into a system of prejudices; its principles would become metaphysical axioms, dogmas, a new kind of revelation.

That is what some scientists come to, who, for fear of falling into literature or metaphysics (as they put it),

[2] Ernst Mach, *The Science of Mechanics*, translated by Thomas J.McCormack, 2d rev. ed., p. 7. Chicago, Open Court Publishing Co., 1902.

[3] See George Sarton, "Les tendances actuelles de l'histoire des mathématiques," *Isis*, Vol. I, pp. 577-589, especially pp. 587-8.

banish all historical or philosophic considerations. Alas! the exclusive worship of positive facts makes them sink into the worst kind of metaphysics—scientific idolatry.

Fortunately it happens at certain periods of evolution that resounding and paradoxical discoveries make an inventory and a thorough survey of our knowledge more obviously necessary to everybody. We are fortunate enough to be living at one of these critical and most interesting periods.

The purpose of historical criticism is not merely to render science more accurate, but also to bring order and clearness into it, to simplify it. Indeed it is the survey of the past that enables us the best to extricate what is really essential. The importance of a concept appears in a much better light when one has taken the trouble to consider all the difficulties that were surmounted to reach it, all the errors with which it was entangled, in short all the life that has given birth to it. One could say that the riches and fertility of a concept is a function of its heredity, and that alone makes it worth while to study its genealogy.

The history of science is accomplishing an endless purification of scientific facts and ideas. It enables us to deepen them, which is undoubtedly the best way to make them simpler. This simplification is of course the more necessary as science grows bigger and more intricate. By the way, it is thanks to this progressive simplification that an encyclopedic knowledge does not become utterly impossible; in certain cases it becomes even more accessible. For instance is it not easier to study chemistry or astronomy—I mean the essentials of it—now than it was, say, in the fifteenth century?

I think one can infer from all the preceding remarks that no scientist is entitled to claim a profound and complete knowledge of his branch if he is not acquainted with its history. I have compared the scientific achievements

of mankind with the collective work that the bees accomplish in their hives. This comparison is particularly apposite to the scientists who have specialized to excess and diligently work in their own narrow field, ignoring the rest of the world. Such men are doubtless necessary, as are the bees that provide honey. But their endeavors could never give birth to a systematic knowledge, to a science proper. It is the more necessary that other scientists raise themselves above the artificial partitions of the different specialties. Their investigations irresistibly lead them to the study of history, and they obtain from it a deeper apprehension of their own collaboration in the grand undertakings of mankind. Just as one experiences gratification by knowing where one is and why, just the same it gives them pleasure to locate their own task in the world's work and to better grasp its relative import. And also, they understand better than the others do the significance of the thousand and one ties that connect them to their fellowmen —and the power of human solidarity, without which there would be no science.

THE PEDAGOGIC POINT OF VIEW.

In many countries one cannot become a teacher at least in the secondary schools, if one has not studied the history of pedagogics. But is it less important to know the history of what is taught? And will not any one who knows this history be better prepared to distinguish what is essential and really interesting from what is not, and to teach his pupils the best of each science? Moreover will the history of science not enlighten the history of pedagogics?

Science is generally taught in a much too synthetic way.[4] It may be that this method is indeed the best for the average student who passively accepts the master's authority. But those whose philosophical mind is more awake

[4] My experience refers especially to the European continent and to the teaching of the physical and mathematical sciences.

can hardly be satisfied by this food, the preparation of which is unknown to them. Instead of being assuaged by harmonious order and perfect science, they are devoured by doubt and anxiety: "Why does the master teach us so? Why has he chosen these definitions? Why?" Not that they are loath to use synthetic methods; on the contrary, these young men will probably be the first to admire the depth and elegance of such teaching once they have grasped from their own experience its logical appositeness, its generality and its economy. But first of all they want to know "how all that was built up," and their mind instinctively recoils from a dogmatism that is still arbitrary to them.

It remains arbitrary indeed so long as the reasons that justify and render natural one arrangement in preference to any other, have not been explained. I know that it is not easy to teach beginners in this way, but at least the deficiencies of the present methods could be tempered, and I do not ask for more.

Nothing would be more useful from this point of view than to work out some text-books in which science would be expounded in chronological order; this is indeed a very important task for which Ernst Mach has given us some admirable models. These text-books would not be employed for elementary study, unless the pupils used them at the same time as others composed along dogmatic lines. Students should have to study the latter and read the first. But in my opinion, these historical text-books would especially stand professors in good stead, by enabling them to illustrate their lessons and make them more intuitive. Oral teaching, more pliable than written teaching, would easily admit of short historical digressions. Would the students not more easily remember the abstract truths that are impressed upon them in ever increasing quantities, if their memory could lay hold of some live facts?

But that does not exhaust the pedagogic importance of

the history of science. Nothing is better fitted to awaken a pupil's critical sense and to test his vocation than to retrace to him in detail the complete history of a discovery, to show him the trammels of all kinds that constantly arise in the inventor's path, to show him also how one surmounts them or evades them, and lastly how one draws closer and closer to the goal without ever reaching it. Besides, this historical initiation would cure the young students of this unfortunate habit of thinking that science began with them.

Good scientific biographies have also a great educational value; they lead an adolescent's imagination in the best direction. Critical and sincere biographies make excellent contributions to the history of mankind. And would not the students work with a better heart and more enthusiasm, would they not have a deeper respect for science, if they knew a little more about the heroes who have built it up, stone by stone, at the expense of so much suffering, struggle and perseverance? Would they not be more eager to undertake some disinterested research work? Or at least would they not better appreciate the greatness and beauty of the whole if they had, more or less, partaken of the joy and intoxication of seeing it accomplished amidst continuous difficulties?

Lastly, the history of science—even more than ordinary history—is a general education in itself. It familiarizes us with the ideas of evolution and continuous transformation of human things; it makes us understand the relative and precarious nature of all our knowledge; it sharpens our judgment; it shows us that, if the accomplishments of mankind as a whole are really grand, the contribution of each of us is in the main small, and that the greatest ought to be modest. It helps to make scientists who are not mere scientists but also men and citizens.

THE PSYCHOLOGIC AND SOCIOLOGIC POINTS OF VIEW.

The history of science, its birth, its evolution, its diffusion, its progress and regressions, irresistibly imposes upon us a series of psychological problems. We here enter the field of universal history, such as the much lamented Karl Lamprecht has defined it; for the history of science in the main amounts to psycho-sociological investigation.

It is necessary here to make a preliminary distinction. The progress of science is due to two different kinds of causes: (1) Purely psychological causes, the intellectual work of the scientist; (2) Material causes, principally the appearance of new subject matter or the use of improved scientific tools. Of course it is not difficult to show that the origin of these material causes is itself more or less of a psychological nature. But the distinction holds good; a discovery has not indeed the same character, the same psychological importance, if it is the almost automatic result of a technical improvement, as if it is the fruit of a mind's reaction. We propose to discover the general laws of the intellectual evolution of mankind, if such laws exist. These studies might also help us to better understand the intellect's mechanism. But of course we have given up the extravagant idea of establishing *a priori* the conditions of scientific development. On the contrary our end is to deduce them from a thorough analysis of all the accumulated experience of the past.

The best instrument for these studies is the comparative method, and this means that we must not expect to reach a degree of accuracy of which this method does not admit. But no scientific work would be possible in the domain of biology and sociology if one did not have the wisdom and patience to be satisfied with the approximation that is within one's reach. The comparisons may be confined to the realm of science; I would call these the internal com-

parisons. They may also be made between the evolution of scientific phenomena and that of other intellectual or economic phenomena; and these I would call the external comparisons. The greatest difficulty of course is to find evolutionary processes that can be adequately compared and that are sufficiently independent one of another.

The application of this method has already supplied some results which have been very improperly called "historical laws," and the exactitude of which is very variable. The following are some examples which I shall refrain from discussing: Paul Tannery has shown that the development of calculus generally precedes that of geometry. In their choice of decorative elements primitive peoples always pass from animals to plants; they never do the contrary. The hypothesis that has been expressed about the course of civilization from the South and the East to the North and the West, is well known. Remember also the law of historical periods proposed by Lamprecht, and especially the famous law of the three states (*la loi des trois états*), formulated by Auguste Comte. The theory of historical materialism, originated by Karl Marx, which has exerted such a deep influence on the thought of the nineteenth century, is also a proper example.

It is sensible to undertake the study of intellectual activities in the same way as we study the industry of the beavers or the bees. Of the work produced by the human brain we generally know nothing but the results, but these are tangible and can be, if not actually measured, at least compared and appraised with more or less precision. The invention of a machine or the discovery of a natural law, are these not at the bottom phenomena of the same kind as the behavior of a crab or of a sea anemone under determined circumstances? They are, of course, much more complex and their study requires the use of new methods, scarcely explored; but can one not admit, at least as a

working hypothesis, that they do not essentially differ? The psychology of the superior functions of the brain is not necessarily more complicated than that of the inferior functions; I should be rather inclined to think the contrary. For instance would it not be easier to retrace the development of a scientific idea in a clear mind than to disentangle, in the prelogical head of a primitive man, the obscure roots of his instinct of property or imitation?

It is from the comparison of these intellectual facts, as they can be collected by the historian of science from the whole intellectual experience of the world, that we may try to deduce the laws of thought. Human experience has been continuously increasing during the ages, but the intellect itself,—has it evolved? The methods of discovery, the mental experiences, the hidden mechanism of intuition —have they not remained somewhat the same? Is there nothing invariable in men's intellectual behavior? What are those invariants, or at least those relative invariants, those more stable parts of our self? To what extent does the scientific environment exert its influence upon the scientists, and *vice versa*? How do social activities evidence themselves in the domain of science? By what mental processes are the ideas of the initiators integrated in the collective thought, to become, by and by, common notions? All these questions, raised by the history of science, are so many psychological problems.

As to research concerning the psychology of invention, choice materials will be found in the history of technology. The results of technical invention are material objects of a very concrete and tangible nature. Besides, the mechanism of industrial discoveries is especially interesting, because to materialize his ideas the engineer has actually to struggle with all the difficulties of real life. The struggle is more obvious here than in any other domain. It happens that unexpected obstacles are so great that the idea cannot

be carried out; but it also happens very often that the very clash of these obstacles gives birth to new ideas, deeper and richer than the original ones. Then one sees, so to say, the invention gush out from the conflict between matter and spirit.

It would be apposite here to present some remarks about the "genealogical" research work that was initiated by Francis Galton and Alphonse de Gandolle. These very interesting historico-statistical investigations, intimately connected with the eugenic movement, bring new testimonies to the importance of the history of science from the psycho-sociological point of view. But to give a good idea of these studies I should be obliged to make too long a digression from my subject. I simply refer the reader to my previous publications on these matters.[5]

THE HUMANISTIC POINT OF VIEW.

A deeper knowledge and a greater diffusion of the history of science will help to bring about a new "humanism." (I beg the reader to excuse me for using a word that has already been employed in at least two different senses, but I do not find any other that is more adequate to the idea I wish to convey.) The history of science, if it is understood in a really philosophic way, will broaden our horizon and sympathy; it will raise our intellectual and moral standards; it will deepen our comprehension of men and nature. The humanistic movement of the Renaissance was essentially a synthetic movement. The humanists were longing for a new atmosphere and a broader conception of life; their curiosity was insatiable. We have at least this much in common with them. We know also that if science were abandoned to narrow-minded specialists it would soon degenerate into a new kind of scholasticism, without life

[5] George Sarton. "L'histoire de la science," *Isis*, Vol. I, pp. 39-41; also, same author, "Comment augmenter le rendement intellectuel de l'humanité?" *Isis*, Vol. I, pp. 219-242, and pp. 416-473 (unfinished).

or beauty—false and wrong like death itself. This would be another good reason for comparing our task with that accomplished by the former humanists. However their movement was essentially toward the past; ours is much more a movement toward the future.

Science, divided into water-tight compartments, makes us feel uneasy;—a world split into selfish and quarrelsome nations (similar to the Italian and Flemish municipalities of the Renaissance) is too narrow for us. We need the full experience of other countries, of other races; we need also the full experience of other ages. We need more air!

It may be useful to lay some stress on the significance of science from the international point of view. Science is the most precious patrimony of mankind. It is immortal. It is inalienable. It cannot but increase. Does not this priceless patrimony deserve to be known thoroughly, not only in its present state but in its whole evolution? Now most men—most scientists—are unfamiliar with the glorious history of our conquests over nature. Would it not be a great work of peace and progress to bring them to better understand and appreciate this intellectual domain which is privileged among all others, *because it is the only one that is entirely common to all*? Science is not only the strongest tie, but it is the only one that is really strong and undisputed.

Science makes for peace more than anything else in the world; it is the cement that holds together the highest and the most comprehensive minds of all countries, of all races, of all creeds. Every nation derives benefit from the discoveries that have been made by the others. There can be no warfare between high-minded scientists.

The further science progresses, the more its international character asserts itself—and this in spite of all jingo-

ist and imperialist tendencies that may occasionally blind and lower some of its servants.

Just as scientific methods are the basis of well-nigh all our knowledge, just so science appears more and more as the bedrock on which every organization has to be built up to be strong and fertile. It is the most powerful factor of human progress. As Mach has perfectly put it: "Science has undertaken to replace wavering and unconscious adaptation by a methodical adaptation, quicker and decidedly conscious." It is the historian's duty to evidence all the scientific facts and ideas that make for peace and civilization; in this way he will better secure science's cultural function.

The international significance of the history of science has not been thus far better grasped for the simple reason that very few historical studies have been inspired by a real international spirit. For one thing universal histories have been almost exclusively devoted to the achievements of the Indo-Aryan race. Everything in them gravitates round the development of Europe. Of course this point of view is absolutely false. The history of mankind is too obviously incomplete if it does not include, on the same level as the Western experience, the immense experience of the East. We badly need the knowledge and wisdom of Asia. They have found other solutions to our own problems (the fundamental problems cannot but be the same), and it is of the greatest importance to consider these solutions, and to consider them in a humble way. It is a fact that they have very often been nearer to truth and beauty than we. Besides, although the development of the Far Eastern countries has been to a great extent independent of our own, there have been far more exchanges, especially in ancient times, than is generally believed, and it is also of paramount importance to investigate these matters.

The progress of mankind is not simply an economic

development; it is much more an intellectual unfolding, as Henry Thomas Buckle has shown with so much force. The whole course of civilization is marked by the triumph of the mental laws over the physical—a triumph of man over nature. To the best of my judgment Buckle has even gone too far in this direction. I am not ready to concede, as he has done, that the changes in every civilized people are dependent solely on three things: (1) The amount of knowledge of the ablest men; (2) The direction of this knowledge; (3) Its diffusion. If Buckle were right all history would be included in the history of science. There are other things to consider.

Moral factors do not deserve to be despised as much as Buckle did, and I think that it is even possible to construct an ethical interpretation of history. To give a moral significance to history the essential condition is to make it as complete, as sincere as possible. Nothing is more demoralizing than histories *ad usum Delphini.* We must display the whole of human experience, the best and worst together. The greatest achievement of mankind is indeed its struggle against evil and ignorance. Nothing is nobler than this endless struggle between the truth of to-day and that of yesterday. It stands to reason that if one side of the picture is not shown—the evil side, for instance—the other loses a great deal of its interest. The quest of truth and beauty is indeed man's loftiness. This is certainly the highest moral interpretation of which history allows.

We must try to humanize science, to better show its various relations with other human activities—its relation to our own nature. It will not lower science; on the contrary, science remains the center of human evolution and its highest goal; to humanize it, is not to make it less important, but more significant, more impressive, more amiable.

The new humanism—as I venture to call the intellec-

tual movement that has been defined in the preceding pages—will also have the following consequences: It will disentangle us from many local and national prejudices, also from many of the common prejudices of our own time. Each age has of course its own prejudices. Just as the only way to get rid of local prejudices is to travel,—similarly, to extricate ourselves from time-narrowness we must wander through the ages. Our age is not necessarily the best or the wisest, and anyhow it is not the last. We have to prepare the next one, and I hope a better one.

If we study history it is not through mere curiosity, to know how things happened in the olden times (if we had no other purpose than this our knowledge would indeed be of a very poor quality); nor is it for the mere intellectual joy of better understanding life. We are not disinterested enough for that. No; we wish to understand, to better foresee; we wish to be able to act with more precision and wisdom. History itself is of no concern to us. The past does not interest us but for the future.

To build up this future, to make it beautiful, as were those glorious times of synthetic knowledge, for instance that of Phidias or of Leonardo da Vinci, it is necessary to prepare a new synthesis. We propose to realize it by bringing about a new and more intimate collaboration between scientist, philosopher and historian. If that were accomplished so much beauty would be given birth to that the collaboration of the artist would also necessarily be secured; an age of synthesis is always an age of art. This synthesis is what I have called "the new humanism." It is something in the making,—not a dream. We see it growing, but no one can tell how big it will grow.

The writer is convinced that the history of science—that is to say, the history of human thought and civilization in its broadest form—is the indispensable basis of any philosophy.—History is but a method—not an aim.

APPENDIX.

THE TEACHING OF THE HISTORY OF SCIENCE IN THE UNITED STATES.

An elaborate essay on this subject has been published in *Science*, November 26, 1915, pages 746-760, by Frederick E. Brasch ("The Teaching of the History of Science; Its Present Status in Our Universities, Colleges and Technical Schools"). As I shall confine myself to remarks of my own and to only a few extracts from Mr. Brasch's work, the reader who desires to follow up the subject is recommended to read his paper.

To Harvard University belongs the credit of first establishing a course on the history of a particular science: Dr. Theodore W. Richards began as early as 1890, and is still continuing, a course on the history of chemistry. On the other hand the Massachusetts Institute of Technology was the first to recognize the interest of the history of science as a whole: Prof. W. T. Sedgwick and H. W. Tyler have been teaching it in that institution since 1905.

According to Mr. Brasch's painstaking statistics, 162 courses on the history of some special science are now organized in 113 schools. Among them not less than 47 are devoted to the history of mathematics, and not less than 38 to the history of chemistry. Moreover there are 9 courses on the general history of science. To this number could be added 8 temporary courses, namely, Harvard Exchange Lectures, delivered by Dr. L. J. Henderson in five Middle Western colleges, and three courses given by myself at the summer school of the University of Illinois, at the George Washington University in Washington, D. C., and at Clark University.

Mr. Brasch gives the following information about the nine regular courses: (1) Reed College: history forms a part of a course on general science; (2) Lehigh University: "combination of biographies and progress of science"; (3) University of Pennsylvania: the philosophy department has started a historical course entitled "Philosophy of Nature"; (4 and 5) Chicago and Columbia: history of the physical sciences; at the University of Chicago there is a course on the history of science in America; (6 to 9) Harvard, Princeton, the Carnegie and the Massachusetts Institutes of Technology have organized complete courses on the history of the physical and biological sciences.

This information is very meagre. For lectures on a subject that is still so far from being standardized it would be most inter-

esting to know exactly what are in each case the purpose and the methods of the lecturer. It would be interesting also to know how many of these courses have been given by specially trained men and how many have been more or less extemporized by professors already engaged in other fields.

It is worth while to note that Prof. W. T. Sedgwick and H. W. Tyler are preparing a text-book for the use of their own classes. Dr. Walter Libby of the Carnegie Institute of Technology is also preparing the edition of a series of short volumes on the same subject. As the interest in it is now awakening it is likely that many other text-books will appear before long.

I have come to the conclusion that the history of science as a whole, brought at least as far as the eighteenth century and including perhaps some rudiments of this history in our own times, should be taught to all undergraduate students. It would be for them the best scientific introduction, and at the same time it would provide them with a historic and philosophic foundation on which they could build up their special studies. It would open their minds and broaden their horizon from the beginning. Such a course should be taught by some one devoting himself entirely to historical research of this kind. On the other hand the complete history of each science during the last fifty or a hundred years should be studied by all the graduate students, making a special study of the same. This course should be taught by specialists of a quite different kind,—not historians, but scientists, having a sufficient historical knowledge,—generally professors of the school for graduate studies.

It may be objected to my plan that the scientific preparation of most undergraduate students is so scanty that they would not be able to attend these lectures with real profit. In this case it would perhaps be better to reserve them for the graduate students, or to shift them to the very end of the university curriculum. In this second hypothesis the course could be made much more complete and be treated from a much higher point of view. It could be a really inspiring course, giving much food for thought to the best students,—a splendid coronation of their studies. It would open their eyes to the marvelous spectacle of human evolution. It would be for them, before their departure from the university, the great humanistic initiation, the supreme lesson of wisdom, of tolerance and enthusiasm.

Some may doubt whether courses on the history of science are really as necessary as I claim. But one thing is certain: If they are given at all they must be given well. A loose and superficial teaching is worse than none. It would soon bring discredit upon historical studies. We must avoid that at all cost. Therefore it is urgent to organize a seminary in at least one of the universities of this country where normal lessons would be given and the historical methods taught in the experimental way. Those who teach the history of science must needs have a first-hand knowledge of it and be trained to make accurate investigations.

There is no seminary for the history of science in this country, but there is one for the history of mathematics at Teachers College of Columbia University, under the direction of Dr. David Eugene Smith. A splendid library and interesting collections have been formed by him at Teachers College, and original research work on the history of mathematics can be conducted there under the best conditions.

Some seminaries also exist in Europe. I know at least two that are equipped for the study of the history of medicine: the famous Institut für Geschichte der Medizin of Leipsic, so efficiently directed by Dr. Karl Sudhoff, and another one in Vienna under the direction of Dr. Max Neuburger. On the other hand the much lamented A. von Braunmühl founded in Munich a seminary devoted to the history of mathematics; and of course much seminary work was also done in Heidelberg, under Moritz Cantor's direction.

There may be other seminaries which I do not recall; but I know positively that there is none devoted to the history of science as a whole. That is not to be wondered at, as these studies are scarcely begun.

I hope that one of the great American universities will take upon itself this initiative, and organize an institute where all information on the history of science could be centralized, studied and diffused again.

Will America give this great example to the world? I earnestly hope so.

BIBLIOGRAPHY.

The John Crerar Library of Chicago published in January, 1911, "A list of books on the History of Science, prepared by Aksel G. S. Josephson." It is the only list of this kind that I know of, and it is very valuable indeed. However it is far from being complete. For one thing it is simply a list of *books*,

and most historical memoirs are not published in book form. I hear that a supplement is being prepared, and also a companion volume on the History of Industry and Industrial Art. I sincerely hope that the Supplement will contain some critical notes, which allow the reader to make a sensible choice between so many titles. Uncritical bibliographies, where the best and the worst books are all put on the same level, sometimes do more harm than good.

The best way to complete the information given by Aksel G. S. Josephson is to refer to the "Bibliographie critique de toutes les publications relatives à l'histoire, à la philosophie, et à l'organisation de la science," published in *Isis*. Unfortunately this publication has been interrupted by the war, and the last list published (Vol. II, pp. 249-310) was closed in May, 1914. Two other lists were prepared, and one was in the press, when Belgium was invaded. The offices of *Isis* are of course inaccessible. But more copies of the periodical are still obtainable from the publisher for Switzerland and Germany: Max Drechsel, Akademische Buchhandlung, Bern, Switzerland.

It may be useful also to refer to the following article: George Sarton, "Soixante-deux revues et collections consacrées à l'histoire des sciences (Bibliographie synthétique...., I), *Isis*, Vol. II, pp. 132-161 (1915).

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